(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 May 2003 (08.05.2003)

PCT

(10) International Publication Number
WO 03/038361 A1

(51) International Patent Classification[7]: F27D 17/00

(21) International Application Number: PCT/US01/42321

(22) International Filing Date:
25 September 2001 (25.09.2001)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **AMEC CAPITAL PROJECTS LIMITED** [GB/GB]; William Press House, Haughton Road, Darlington DL1 2ED (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **THOMPSON, Leo, E.** [US/US]; 9014 West John Day Avenue, Kennewick, WA 99336 (US). **LOWERY, Patrick, S.** [US/US]; 714 South Penn Place, Kennewick, WA 99336 (US). **WOOSLEY, Steven, L.** [US/US]; 4108 Mojave Court, Pasco, WA 99301 (US).

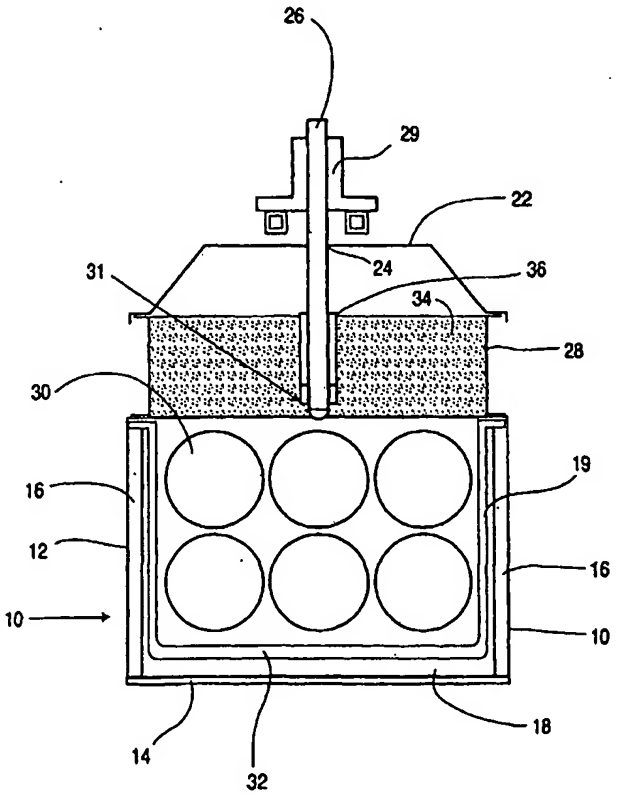
(74) Agents: **HEIMBECHER, Reed, R.** et al.; Dorsey & Whitney LLP, Republic Plaza Building, Suite 4700, 370 Seventeenth Street, Denver, CO 80202-5647 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF,

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR VITRIFICATION OF CONTAMINATED SOIL OR WASTE



(57) Abstract: A process for vitrifying contaminated waste material (30) includes providing a container (10) including an insulating lining (16), placing the waste material (30) in the lined container (10), subjecting the material (30) to an electric current to heat and melt the material (30), cooling the molten material to form a solid vitrified mass, and disposing said mass. The mass is disposed while contained in the container (10). The insulating lining (16) may comprise one or more layers of a thermal insulating material (19), one or more layers of refractory material (18), or a combination thereof.

WO 03/038361 A1

CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— *of inventorship (Rule 4.17(iv)) for US only*

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

APPARATUS AND METHOD FOR VITRIFICATION OF CONTAMINATED SOIL OR WASTE

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The present invention relates to a method and apparatus for vitrification of soil or waste materials. More specifically, the invention relates to an apparatus that comprises a vitrification chamber and disposal container, which enables a one step disposal method for contaminated materials.

DESCRIPTION OF THE PRIOR ART

[0002] The use of vitrification methods for safely disposing contaminated soil or waste materials (hereinafter referred to as material to be treated) is known in the art. Examples of such methods are provided in US patent numbers: 4,376,598; 5,024,556; 5,536,114; 5,443,618; and, RE 35,782. The disclosures of these patents are incorporated herein by reference.

[0003] Generally, the known vitrification methods involve placement of the material to be treated into a vitrification chamber or vessel. Electrodes are then introduced into the material and a high current is supplied there between. Application of the current is continued until the temperature of the material is raised to the point where the material begins to melt and is continued until the material is completely melted. If certain cases, other additives may be required to provide an initial electrically conductive resistance path through the material to be treated if such material is not capable of adequate current conduction. Once the resistance path is initiated and melting of the material begins, the molten material itself will continue current conduction.

[0004] In the course of melting the material, hydrocarbon components are destroyed or vaporized and the gases are normally vented through a suitable scrubber, quencher, filter or other known device or method.

[0005] Once the material is sufficiently melted and all hydrocarbon components are treated, the electricity supply is terminated and the molten material allowed to cool. The cooling step then results in a vitrified and/or crystallized solid material. In this manner,

contaminants are immobilized within a solid, vitrified mass thereby ensuring containment of the contaminants and facilitating disposal of same.

[0006] In the known methods, vitrification is accomplished within a complex crucible apparatus or within a pit dug into the soil. In US patent 5,443,618, an example is provided of a vitrification apparatus comprising a chamber that is either permanently in place (as in a treatment facility) or one which can be dismantled and reassembled at desired locations. In each case, the molten mass is removed from the chamber and processed further separately. Such further processing may involve burial of the vitrified mass or other type of disposal. The apparatus known in the art for conducting vitrification process are normally complex structures including various electrical supply systems, waste feed systems, molten glass discharge systems, cooling systems and venting systems. With such systems, require the removal of the melted mass while in the molten state, hence requiring the above mentioned molten glass discharge systems. In these cases, the melt is either poured or flowed out as a molten liquid into a receiving container.

[0007] In US patents 4,376,598 and RE 35,782, vitrification processes within a pit are described. In this case, the material to be treated is dumped into a pit or trench in the ground and a soil or other type of cap is placed as a cover. Electrodes are then introduced to conduct the vitrification process as described above. Once the process is completed, the vitrified mass is left buried in the ground. As will be appreciated, certain contaminants such as radioactive waste etc. cannot safely be disposed in this manner as they must be disposed of in designated burial locations.

[0008] Therefore, there exists a need for a vitrification apparatus and method that overcomes various deficiencies in the prior art.

SUMMARY OF THE INVENTION

[0009] Thus, in one embodiment, the present invention provides a process for vitrifying waste and/or hazardous material comprising:

- providing a container for containing said material, said container including an insulating lining;
- placing said waste or hazardous material in said container;
- inserting at least one pair of electrodes into said waste or hazardous material;
- sealing said container with a first cover;

- passing current between said pair of electrodes for a time and power level so as to melt said waste or hazardous material; and,

- cooling said molten material until such material forms a solid, vitrified mass.

[0010] In another embodiment, the present invention provides a container for vitrifying waste or hazardous material comprising a box, said box including an inner lining comprising one or more layers of a thermal insulating material, one or more layers of a refractory material or a combination thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] These and other features of the preferred embodiments of the invention will become more apparent in the following detailed description in which reference is made to the appended drawings wherein:

Figure 1 is an end cross sectional elevation view of a container according to an embodiment of the present invention.

Figure 2 is an end cross sectional elevation view of an apparatus including the container of Figure 1 when in use according to an embodiment of the invention.

Figure 3 is an end cross sectional elevation view of an apparatus including the container of Figure 1 when in use according to another embodiment of the invention.

Figures 4a to 4d are end cross sectional elevation views of the apparatus of Figure 3 in various stages of the melting process of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] As discussed above, traditional vitrification processes have been conducted in pits or in complex chambers. The present invention, however, provides a container into which the contaminated material to be treated is placed and in which the vitrification process is conducted. Moreover, the container is manufactured in such as a manner as to be easily disposable once the vitrification process is completed. This avoids the need to remove and handle the molten or vitrified mass, thereby providing a safe and easy means of waste disposal.

[0013] The container of the present invention may be used in virtually all types of vitrification processes. For example, the container and process may be used for various

contaminant types such as heavy metals, radionuclides, and organic and inorganic compounds. Concentrations of the contaminants can be of any range. Further, the invention can be used with all soil types such as, for example, sands, silts, clays, etc. The soil to be treated may be wet or comprise sludges, sediments, or ash.

[0014] As indicated above, the general vitrification process involves electric melting of contaminated soil or other earthen materials for purposed of destroying organic contaminants and immobilizing hazardous and radioactive materials within a high-integrity, vitrified product. The process is initiated by placing electrodes within the material to be treated, followed by placement of a conductive starter path material between the electrodes. When electrical power is applied, current flows through the starter path, heating it up to the point that it melts the soil and waste adjacent to it. When the adjacent soil and waste becomes molten, they become electrically conductive, and from that point on, the molten material serves as the heating element for the process. Heat is conducted from the molten mass into adjacent un-melted soil and waste, heating it also to the melting point, at which time it becomes part of the heating element. The process continues by increasing the amount of material melted until the supply of electric power is terminated. During the melting or vitrification process, any off gases are captured and, where necessary, treated in a suitable, known manner. The vitrified mass resembles a glass and crystalline product and immobilises non-gassified contaminants such as heavy metals and radionuclides etc. The vitrification process has a high tolerance for debris such as steel, wood, concrete, boulders, plastic, bitumen, tires etc.

[0015] For typical soil materials, the melting process is performed in the temperature range of about 1400° to 2000°C, depending primarily on the composition of the materials being melted. Melts of various sizes and shapes can be produced.

[0016] In a preferred embodiment of the present invention, the vitrification process involves the use of a steel container such as a "roll-off box", which is commonly available. In accordance with the present invention, the container is first insulated to inhibit transmission of heat, and is also provided with a refractory lining inside the box to protect the box during the melting step. The waste or soil material to be treated is placed within the box. Electrodes are then introduced into the material and the melting process is conducted as described above. Once melting is complete, the contents of the box are allowed to cool and solidify. Subsequently, the box is then disposed of along with the vitrified contents. In an

alternate embodiment, the vitrified contents can be removed from the box and disposed of separately, thereby allowing the box to be re-used.

[0017] Figure 1 illustrates a treatment container according to one embodiment of the present invention. As illustrated, the container 10 comprises a box having sidewalls 12 and a base 14. The container 10 is provided with a layer of insulation 16 on each of the sidewalls 12 and the base 14. After placement of the insulation, the container is lined with a refractory material 18, such as sand. The refractory material is provided so as to line the sides as well as base of the container. In this manner, a space 20 is left into which the material to be treated can be placed. In a preferred embodiment, the refractory material is further lined with a plastic liner 19.

[0018] Figure 2 illustrates one embodiment of the present invention. As shown, the container of Figure 1 is provided with a hood 22. The hood 22 is positioned over the container 10 and seals the top thereof. The hood is provided with openings 24 through which extend electrodes 26.

[0019] Between the hood 22 and the container 10, may be placed a connector 28, which connects the hood 22 to the container 10.

[0020] As shown in Figure 2, after the insulation 16 and refractory material 18 are placed in the container 10, drums of the waste material 30 are then placed within the space 20. The drums may, for example, comprise standard 55 or 30 gallon drums. Void spaces between the drums 30 are filled with soil 32. Such soil, 32, is also provided to cover the drums. Further, a layer of cover soil 34 is placed over the covered drums and extends into the connector 28. An electrode placement tube 36 extends through the cover soil 34. The electrodes 24 for the treatment process extend through the placement tube 36.

[0021] Figure 3 illustrates another embodiment of the invention wherein compacted drums 30a or any other waste materials are provided in the container 10 instead of cylindrical drums as shown in Figure 2.

[0022] The present invention will now be described in terms of the steps followed. First, the containers are, as described above, lined with a thermal insulation board, followed by placement of a slip form to facilitate the installation of a layer of refractory material (i.e. a material having a very high melting point such as silica sand. A plastic liner is then placed in the container so that waste materials and soil can be staged within the plastic liner. The plastic liner may be used to contain liquids prior to treatment when the waste material to be

treated contains appreciable liquids. The slip form may be removed once the waste material is emplaced.

[0023] As described below in the example, the waste material to be treated can be placed within the container in drums. Within the drums, the waste material can be compacted to maximize the amount of the material to be treated. Alternatively, in another embodiment, the material to be treated can be placed directly into the container without the need for drums. In another embodiment, the material to be treated can be placed within the container in bags or boxes. In still another embodiment, liquid wastes can be mixed with soil or other absorbents and placed in the container.

[0024] In another embodiment, the steel container, as described above, can be placed within a concrete or steel cell prior to the vitrification step. Such concrete cell is provided with the necessary electrical supply and off-gas treatment facilities required for the vitrification process.

[0025] As will be understood by persons skilled in the art, various additives may be added to the waste material to improve or enhance the process of the invention. For example, such additives may increase the conductivity of material (e.g. Na^+) or aid in oxidizing metals contained in the material (e.g. sucrose, $KMnO_4$).

[0026] In one embodiment, the containers of the present invention can be standard "roll-off" boxes ranging in volume from 10 to 40 cubic yards. Such containers or boxes will have any variety of dimensions of length, width and height. As will be appreciated by persons skilled in the art, the dimensions of the box will be limited only by the requirements of any apparatus that must be attached thereto. In another embodiment, the container of the invention may comprise metal drums, such as standard 55 gallon steel drums. Such drums can be provided with the required insulation and/or refractory material layers as discussed herein. The wall thickness of the containers of the invention can also vary. Typically, standard boxes have wall thicknesses that are in the range of 10 to 12 gauge; however, as will be apparent to persons skilled in the art, other dimensions are possible.

[0027] Typically, the containers of the present invention will be provided with insulation that is in the form of an insulation board that is 1 to 2 inches in thickness. The refractory sand material may be provided in a thickness of 4 to 8 inches and up to 12 inches at the base.

[0028] In general terms, the insulation and refractory material form a liner or liner system in the interior of the container. Such liner serves to maintain heat within the container so as

to increase the efficiency of the melting process. With this in mind, it will be appreciated that the refractory material, or sand, can also serve as an insulating layer. In such case, the thickness of the refractory material in the container may be increased to provide the needed insulating value. Alternatively, the refractory material may be omitted and only an insulating layer provided in the container. In the case where both a refractory layer and separate insulating layer is used, the refractory material would also serve to direct heat away from the insulating layer. In such case, it would be possible to extract the insulating layers from the container after the vitrification process and re-use them. In another embodiment, multiple layers of insulating and/or refractory liners may be used. As will be understood, the amount of insulating and/or refractory material would depend, amongst other criteria, on the nature of the soil and waste materials being treated. For example, if such soil and material has a high melting temperature, then extra insulating and/or refractory material would be required.

Example

[0029] The invention will now be described with reference to a specific example wherein radioactive substances, such as uranium, are involved. It will be understood that the example is not intended to limit the scope of the invention in any way.

[0030] First, the waste material is placed within 30 gallon drums. The drums, containing the waste material, are then compressed or compacted and placed within 50 gallon drums and packed with soil and sealed. These latter drums are then introduced into the treatment container 10. During the compression of the smaller drums, any oil in the waste material may need to be removed and treated separately, as described further below.

[0031] The placement of the compacted drums of material to be treated (e.g. uranium and oil) into the container 10 can be performed in two ways. The first method involves emptying of the 55-gal drums holding the compacted smaller drums and soil into the container 10. The compacted drums would be immediately covered with soil to prevent free exposure to air. In this method, the compacted drums may be staged more closely together for processing, and a higher loading of uranium can be achieved. In addition, by removing the compacted drums from the 55-gal drums, there would be no requirement to ensure that the 55-gal drums were violated or otherwise unsealed so as to release vapours during the vitrification phase.

[0032] Alternatively, the 55-gal drums containing the compacted drums could be placed directly into the waste treatment containers for treatment. In this case, vent holes will be installed into the drums to facilitate the release of vapours during processing.

[0033] Some of the contaminated oil (11 wt%) removed during the compression phase of the smaller (30 gallon) drums can be added to the soil in the treatment volume in the container for processing with the drums of uranium. The plastic liner 19 will prevent the movement of free oil from the waste materials into the refractory sand materials 18. The slip form will be raised as the level of waste, soil, and refractory sand are simultaneously raised, until the container is filled to the desired level. At that point the slip form will be removed to a storage location.

[0034] A layer of clean soil is placed above the staged waste and refractory sand. Electrodes are then installed into the soil layer. The installation of the electrodes may involve the use of pre-placed tubes to secure a void space for later placement of electrodes 26. A starter path is then placed in the soil between the electrodes. Lastly, additional clean cover soil 34 is placed above the starter path 31. This will conclude the staging of the waste within the treatment container. The configuration of the waste treatment containers after waste staging is shown in Figures 2 and 3.

[0035] Once the waste treatment container 10 is staged with waste as described above, it is covered with an off-gas collection hood 22 that is connected to an off-gas treatment system. Electrode feeder support frames 27, to support electrode feeders 29, are then positioned over the container-hood assembly 22 unless they are an integral part of the hood 22 design, in such case they will already be in position. An electrode 26 is then placed through the feeder 29, into the hood 22 and into the tube 36 placed at the end of the starter path 31. Additional starter path material will be placed within the tube 36 to ensure a good connection with the starter path 31. Finally the remainder of the tube will be filled with clean cover soil 34. This will complete the preparation of materials for melting. It will be appreciated that although the above discussion has been directed to a single electrode, the container will be provided with at least a pair of electrodes, each including similar requirements as indicated above. Indeed, as will be apparent to persons skilled in the art, any number of electrode pairs may be provided in the system.

[0036] Commencement of off-gas flow and readiness testing will be performed prior to initiation of the melting process. The melt processing will involve application of electrical

power at an increasing rate (start-up ramp) over a period of time and at a given power output value. For example, electrical power may be applied for about 15 hours to a full power level of approximately 500 kW. It is anticipated that processing of waste containing uranium, drums and oil may take a total of two (2) to five (5) days cycle time to complete depending on the type of waste being treated, the power level being employed and the size of the container. Preferably, processing will be performed on a 24-hr/day basis until completed.

[0037] Figures 4a to 4d illustrate the progressive stages of melting of the material within the container 10.

[0038] Although the invention has been described with reference to certain specific embodiments, various modifications thereof will be apparent to those skilled in the art without departing from the spirit and scope of the invention as outlined in the claims appended hereto.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A process for vitrifying waste and/or hazardous material comprising:

- providing a container for containing said material, said container including an insulating lining;
- placing said waste or hazardous material in said container;
- inserting at least one pair of electrodes into said waste or hazardous material;
- sealing said container with a first cover;
- passing current between said pair of electrodes for a time and power level so as to melt said waste or hazardous material; and,
- cooling said molten material until such material forms a solid, vitrified mass.

2. The process of claim 1 further comprising:

- removing said first cover;
- re-sealing said container with a second cover;
- disposing said container containing therein said vitrified mass.

3. The process of claim 1 wherein any gasses generated during said melting step are collected and/or treated before being vented.

4. The process of claim 3 wherein said first cover includes a means to collect said gasses.

5. The process of claim 1 wherein said container includes a further, liquid impermeable inner liner, whereby any liquids contained in said waste or hazardous material is prevented from contacting said refractory material prior to said melting step.

6. The process of claim 1 wherein said waste or hazardous material comprises contaminated soil.

7. The process of claim 6 wherein said waste or hazardous material contains contaminants chosen from the group consisting of hydrocarbons, radioactive materials, radionuclides, carcinogens, or any combination thereof.

8. The process of claim 1 wherein said insulating lining comprises one or more layers of a thermal insulating material, one or more layers of a refractory material or a combination thereof.

9. A container for vitrifying waste or hazardous material comprising a box, said box including an inner lining comprising one or more layers of a thermal insulating material, one or more layers of a refractory material or a combination thereof.

Figure 1

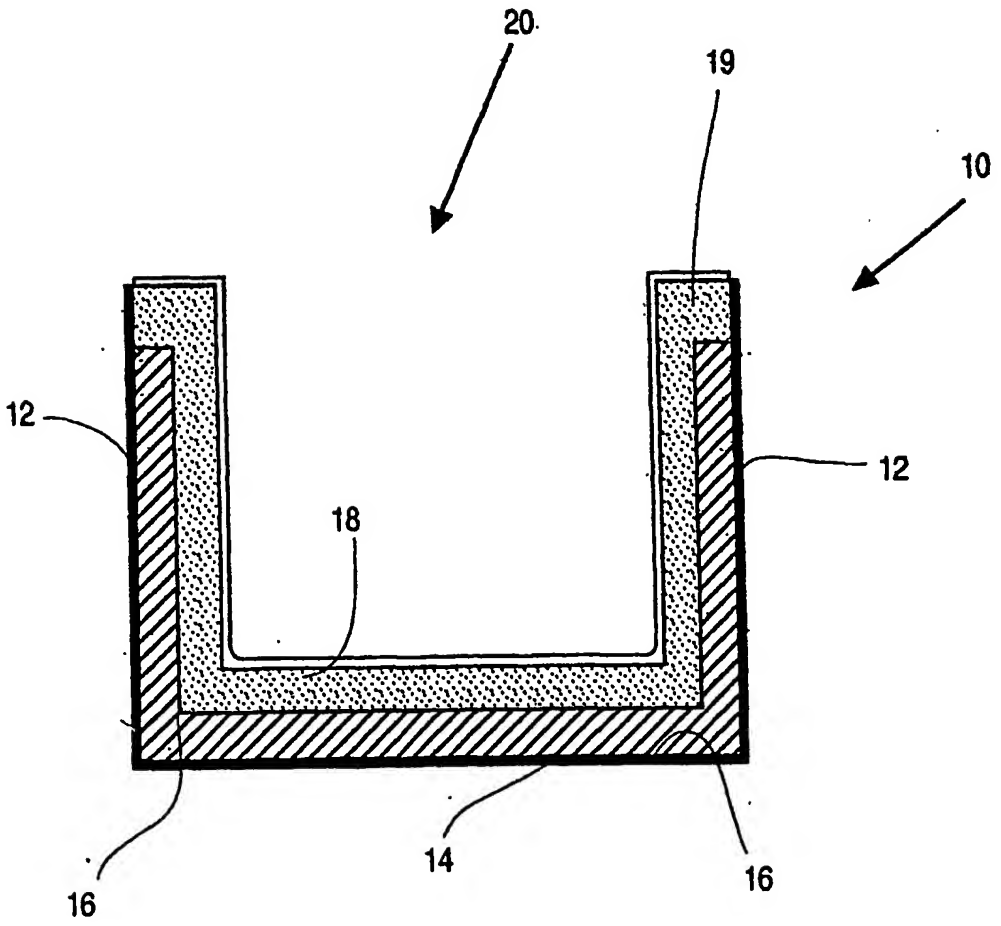


Figure 2

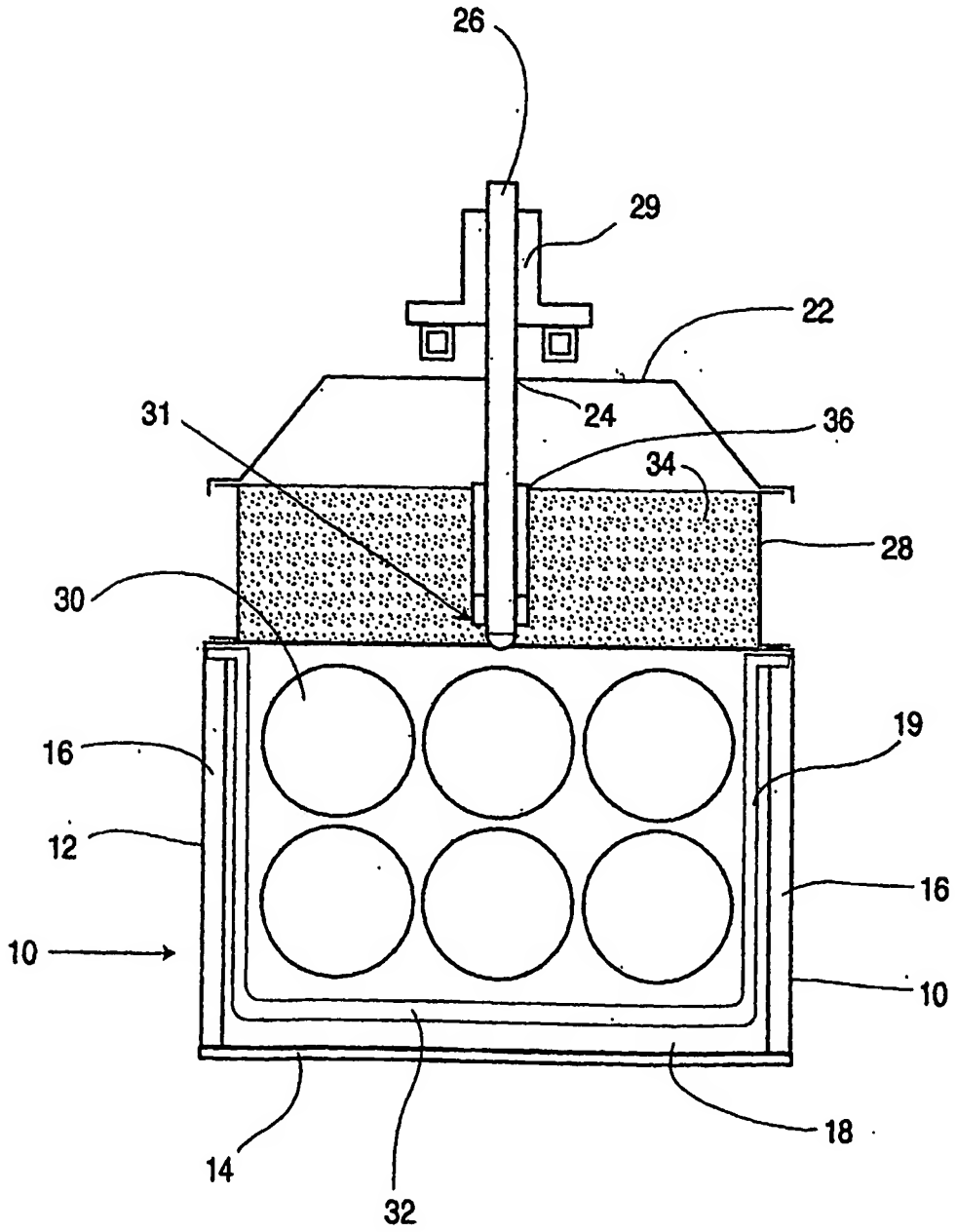
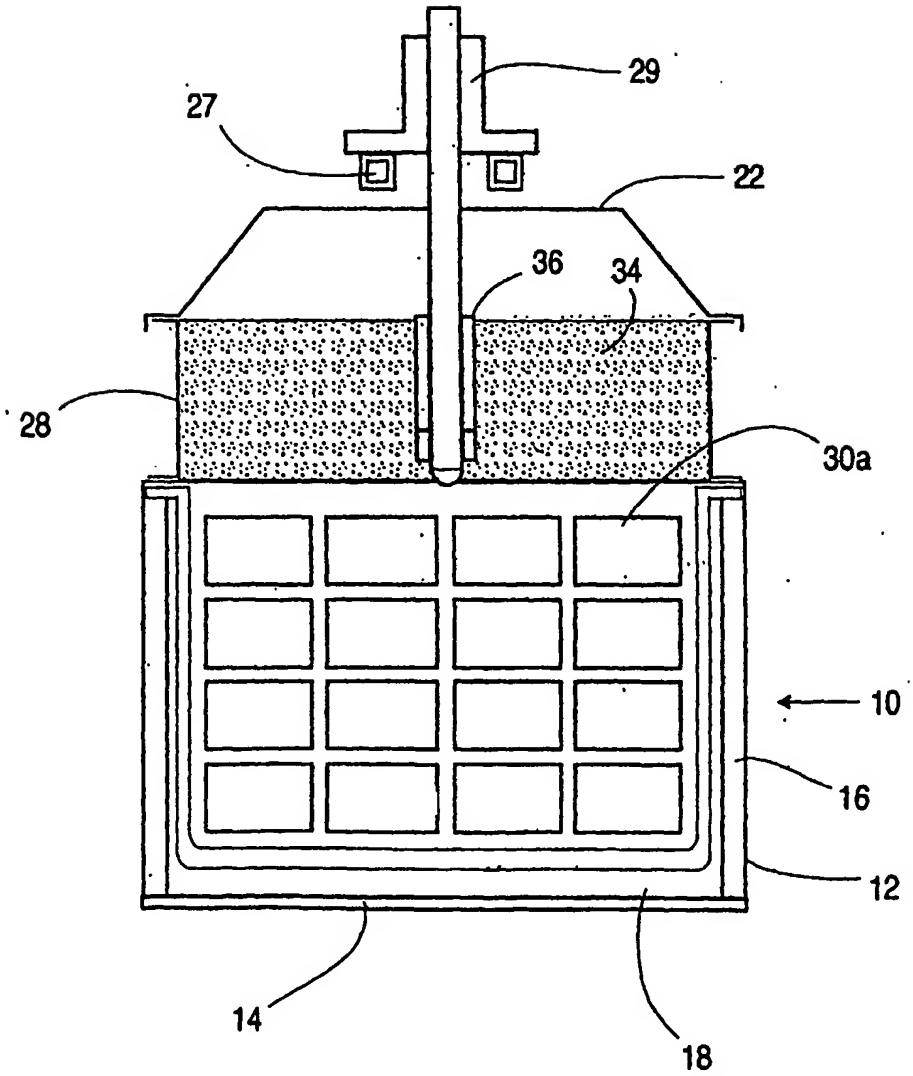


Figure 3



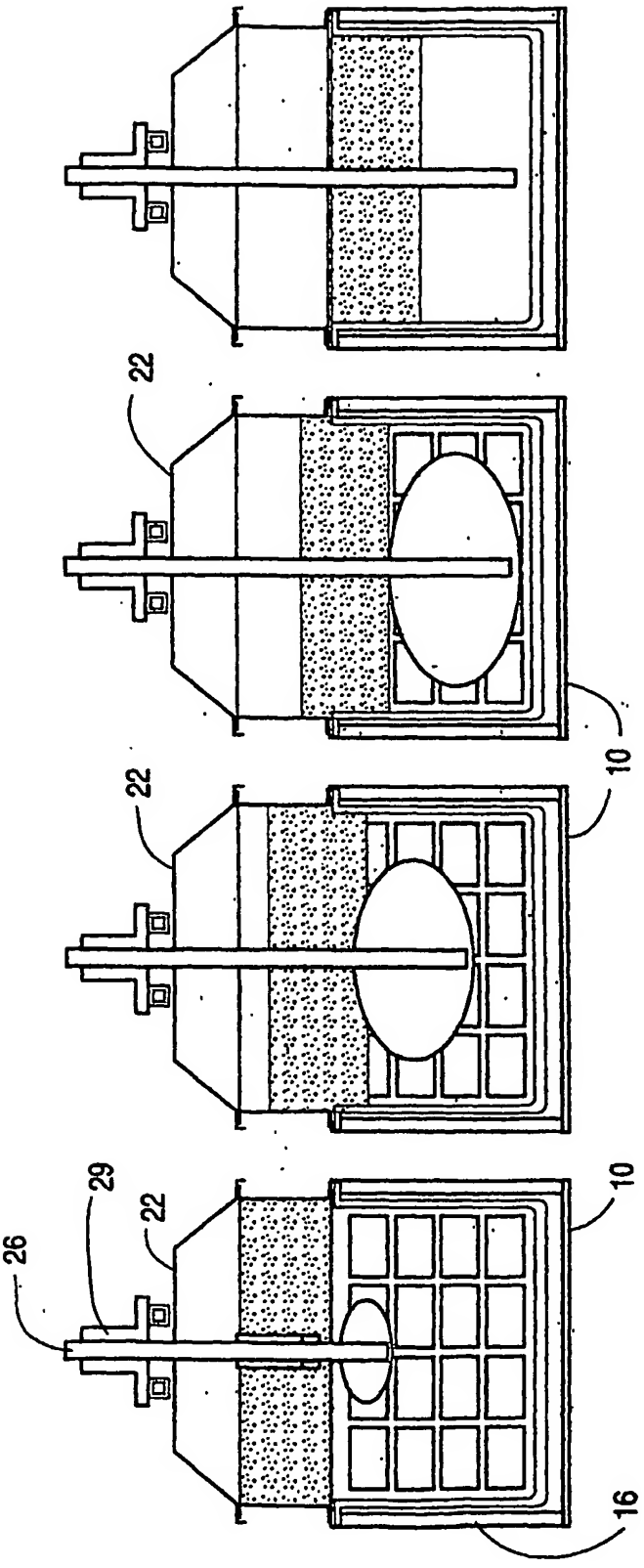


Figure 4D

Figure 4C

Figure 4B

Figure 4A

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/42321

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : F27D 17/00
US CL : 373/9
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 373/2,8,9,30,36-3960-62,71-77; 65/27,134.6,136.1; 405/128,258; 588/237

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,673,285 A (WITTLE et al) 30 September 1997, see the entire reference.	1,3-4, and 6-9.
X	US 5,443,618 A (CHAPMAN) 22 August 1995, see the entire reference.	9
X	US 4,660,211 A (STRITZKE) 21 April 1987, see the entire reference.	9
X	US 5,062,118 A (MASAKI) 29 October 1991, see the entire reference.	1, 3-4, and 6-9
A	US 5,319,669 A (COX et al) 07 June 1994, see the entire reference.	1-9
A	US 5,926,498 A (MECHTERSHEIMER) 20 July 1999, see the entire reference.	1-9
A	US 5,536,114 A (WETMORE et al) 16 July 1996, see the entire reference.	1-9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 December 2001 (13.12.2001)	16 JAN 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Tu Hoang T. Hurley for Telephone No. (703) 308-3303

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/42321

Continuation of B. FIELDS SEARCHED Item 3:
EAST,WEST
search terms: vitrifying,waste,electrodes